Radio Broadcasting Transmitters and Related Transmission Phenomena [1]

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This paper is a brief discussion of recent developments in American practice concerning radio broadcasting transmitters. Descriptive material and photographs pertaining to several new commercial transmitting equipments are included. Reference is also made to the more important aspects of the related transmission problem. On account of the scope of the subject, the treatment is necessarily superficial, but it may serve to indicate the present status of the transmitter art and its relative position with respect to the industry as a whole. A short bibliography containing some of the more important recent contributions to the subject is attached as an appendix, to which reference may be had for more detailed information.

Radio Transmitters

THE radio transmitter is essentially a focal point in the present-day broadcasting system, since upon it the program circuits converge and from it the radio distribution network emanates. For this reason, the requirements which have been imposed on transmitting apparatus are extremely rigorous, and all phases of transmitter performance have been subjected to the most careful scrutiny. Under these stimulating influences, the last few years have brought about some very noteworthy advances in this portion of the broadcasting field.

As long as music and entertainment continue to hold a prominent place on broadcasting programs, fidelity of transmission will probably remain the most sought-for characteristic, not only for the radio transmitter itself, but for all of the apparatus units in the system. A very high standard of performance has now been attained in this respect. Fig. 1, below, shows the overall frequency-response characteristic of a new type 50-kw. equipment, the first of which has gone into service at one of the leading American broadcasting stations within the past few months. It will be noted that this characteristic is substantially flat between 30 and 10,000 cycles. The greatest departure from the horizontal line which is the ideal characteristic is less than 1 db. The frequency discrimination which this represents is of such a low order that it probably could not be detected in ordinary listening tests, even by a skilled musician.

Another recognized prerequisite to a high degree of fidelity is exact proportionality between audio input and sideband output. Increased

[1] Read before the World Engineering Congress, Tokio, Japan, October, 1929; *Proceedings of Institute of Radio Engineers*, November, 1929.

emphasis on accurate reproduction has recently led to the introduction of improved technique for checking this important characteristic under dynamic conditions. The method employed consists of impressing a pure sine-wave input on the transmitter at various frequencies throughout the audio range and subjecting the output of

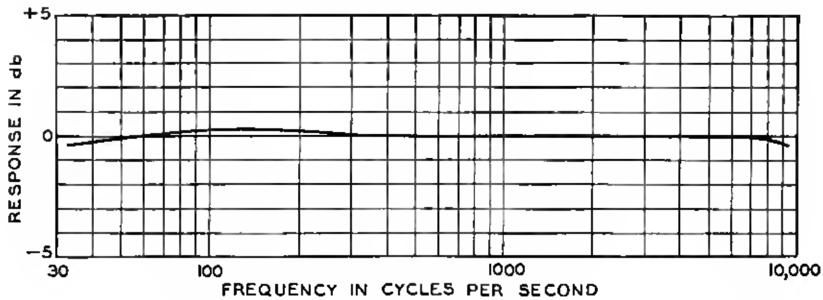

Fig. 1—Frequency-response characteristic of Western Electric 7-A (50-kw) radio transmitter.

a straight-line rectifier to harmonic analysis. One type of harmonic analyzer which has been used with excellent results is that due to Wegel and Moore.[2] This device produces a photographic record, an example of which is shown in Fig. 2. Measurements of this type are

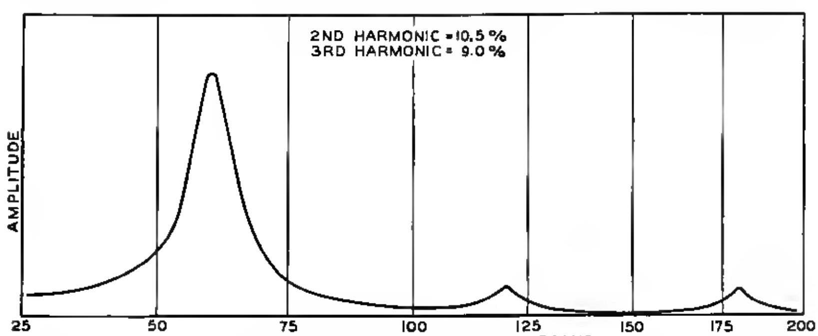

Fig. 2—Harmonic analyzer graph indicating overloading (2nd harmonic, 10.5 per cent; 3rd harmonic, 9 per cent).

of particular importance under present conditions since current American practice is tending toward the extensive use of transmitters in which modulation is accomplished at relatively low power levels and the required power output is obtained by means of subsequent stages amplifying modulated radio-frequency power. Such amplifying stages

[2] R. L. Wegel and C. R. Moore, "An Electrical Frequency Analyzer," *Bell Syst. Tech. Jour.*, p. 299–323, April, 1924.

are susceptible of serious amplitude distortion unless the conditions under which the tubes operate (direct plate and grid voltages and impedance of the connected load) are carefully predetermined. For this purpose, the harmonic analyzer has proved to be invaluable. Through its use, commercial transmitters are now available in which, at the working upper limit of modulation, the harmonics generated are not greater than 5 per cent.

The attainment of such high standards for fidelity leaves little opportunity for progress, and it is improbable that significant advances in this direction will be made in the near future. Accordingly, in continuing their efforts toward further improvements in broadcasting service, transmitter engineers have been led to divert their attention to the problem of rendering less conspicuous and objectionable the background of noise and interference which, in the past, has so seriously impaired the artistic effect of programs except in the immediate vicinity of transmitting stations. This is the principal justification for the present movement toward higher power outputs for broadcasting stations. It has also resulted in increased emphasis on the maintenance of a high average degree of modulation, a development which is rapidly bringing about a very perceptible improvement in general broadcasting conditions.

The degree of modulation of the carrier in a radio telephone transmitter is a somewhat intangible factor which necessarily varies rapidly through wide limits during the rendition of a program. With every transmitter, however, there is a definite modulation limit which is a characteristic of the design and which cannot be exceeded without bringing about serious distortion. This limit is an important performance index which, for lack of a better name, has been called "modulation capability." The modulation capability of a transmitter may be defined as the maximum degree of modulation (expressed as a percentage) that is possible without appreciable distortion, employing a single-frequency sine-wave input and using a straight-line rectifier coupled to the antenna in conjunction with an oscillograph or harmonic analyzer to indicate the character of the output.

For a number of reasons, some technical and some economic, many of the broadcasting transmitters in use have been so constructed that overloading of the audio power stage with consequent distortion occurs whenever the degree of modulation exceeds approximately 50 per cent. The usual practice in placing broadcasting transmitters into service consists of determining, by means of a suitable vacuum-tube voltmeter or other "volume indicator," the audio level at the input of the set for which distortion becomes evident. The average

operating level is then established at a suitably lower value, frequently 6–10 db. Recently, by modulating at low power levels, transmitters have been produced which are capable of 100 per cent modulation without noteworthy distortion. It is obvious that, if a transmitter of this latter type is employed and the same margin is observed in determining the average audio input level, the resulting sidebands will be twice the amplitude of those produced by a transmitter whose modulation capability is only 50 per cent. To produce equivalent sidebands with a transmitter capable of but 50 per cent modulation requires that the carrier amplitude be doubled or the power output multiplied by four. In other words, insofar as signal-to-noise ratio is concerned, which is the factor that usually determines the coverage of a broadcasting station, the increase in modulation capability mentioned results in an improvement that in the older type of apparatus could only be had by quadrupling the rated output of the transmitter. From the coverage standpoint, the night range of a given station can be approximately doubled in this manner. Since this is accomplished without increase in the carrier power, the outlying zone in which the station may produce serious beatnote interference with others assigned to the same channel will not be extended. Accordingly, the use of transmitters capable of a high degree of modulation is a notable contribution toward the more effective utilization of the medium, which is the outstanding technical problem in American broadcasting today.

Another important factor, from the standpoint of intensive development of the available frequency band, is frequency maintenance. In a system involving so many stations as are now operating in the United States, accurate maintenance of the assigned frequencies presents a very difficult problem. The maximum deviation permitted by the existing government regulations ($\pm$ 500 cycles) is somewhat beyond the capabilities of the ordinary wavemeter and difficulty has been experienced in obtaining a satisfactory substitute. In the absence of adequate frequency control apparatus, very serious beatnote interference has been of frequent occurrence. During the past year, however, considerable improvement has been brought about by the extensive adoption of piezo-electric reference oscillators and automatic piezo-electric control. Equipment for the latter purpose capable of a relatively high standard of performance is now being offered commercially and it is probable that apparatus of this type will be installed in the near future by the majority of stations. Its use is expected to avoid entirely heterodyne interference on the "cleared" channels, where the beatnotes are those produced between the carriers of sta-

tions having adjoining frequency assignments. There is also reason to believe that the general adoption of such apparatus will materially improve conditions on the "shared" channels, each of which is occupied by several stations located at suitable distances, provided the assigned frequencies can be maintained with sufficient accuracy to preclude the reproduction of audible beats or other objectionable interference effects.

This problem of "synchronization," or preferably "common frequency operation," is beginning to receive considerable attention from all factors in the broadcasting industry. It promises important contributions in at least two directions:

(1) Improvements in the coverage of a common service area by two or more stations all broadcasting the *same* program;
(2) The attainment of minimum geographical spacings between stations operating on the same nominal frequency and broadcasting *different* programs.

The degree of frequency maintenance required for these two cases is apparently quite different. For case (1), the evidence indicates that very rigorous requirements must prevail. The most successful operations of this type have employed wire lines connecting the stations for the transmission of a base frequency from which the carriers were derived by means of harmonic generators. For case (2), however, there is reason to believe that comparatively wide limits will suffice.

Expeıience has shown that if the entertainment value of a program is not to be seriously impaired by interference, the ratio of wanted to unwanted carrier at the receiving point, in terms of field intensity, must be at least 100 : 1. From a relative interference standpoint, the significant factors are the wanted sidebands, the unwanted sidebands and the unwanted carrier, each of which produces a component in the detector output by interaction with the wanted carrier. With equal modulation at both stations, which is one of the conditions assumed, the ratio of the audio components due to the sidebands will, in general, be approximately the same as that between the carriers, or 100 : 1, representing a difference in level of 40 db. Due to the frequency difference between carriers, demodulation of one of the unwanted sidebands will result in the original signal with each of its elements shifted upward in pitch by an amount corresponding to this difference, while the other sideband will produce a signal which is similarly displaced in the reverse direction. The interfering signal may be badly garbled, therefore, but its disturbing

effects insofar as enjoyment of the program is concerned will be substantially unaffected. The beatnote, which results from the interaction of the unwanted and wanted carriers, will be 6–10 db above this sideband interference level if average practice, as previously described, is followed. From this analysis, it appears that if the beatnote can be held to a value below the lowest frequency which it is desired to transmit and if one of the circuit elements of the reproducing system can be designed to provide some 10 db discrimination against the beat frequency, interference due to the latter can be so subordinated that the service areas of the stations involved will be defined by the limiting condition assumed for sideband interference, or a 100 : 1 ratio between carrier field intensities. Under these circumstances, no beatnote interference will be experienced in those areas where reasonably good service can be given. In adjoining regions, where the carrier ratio is less than 100 : 1, beatnote interference may continue to be observed but is of no importance since satisfactory reception in such areas is precluded by the sideband interference.

To meet the requirements outlined, it is probable that ultimately frequencies will have to be maintained to approximately 10 cycles, which would result in a maximum beatnote near the lower limit of aural frequency response. Such precision seems hardly necessary, however, under the conditions existing at the present moment. Almost all loud speakers now commercially available discriminate notably against frequencies below 100 cycles. A material improvement in beatnote conditions could probably be brought about, therefore, by the adoption of automatic control apparatus capable of maintaining the assigned frequencies to $\pm$ 50 cycles. Such performance is within the capabilities of the piezo-electric apparatus now available. Under the circumstances it is expected that considerable progress will be made in this direction during the coming year.

The foregoing considerations lead to the formulation of an important system requirement affecting receiving apparatus, which in this case includes both the radio receiver proper and the loud speaker. In a system involving a relatively large number of stations assigned to cleared and shared channels at 10-kc. intervals, such as exists in the United States, beatnote interference in the form of components at approximately zero cycles and at 10 kc. is an inherent characteristic. If a maximum frequency deviation of $\pm$ 10 cycles is accepted as the ultimate limit, in order to avoid such interference the receiving apparatus must be so designed that at frequencies below 20 cycles and above 9,980 cycles there will be introduced sufficient attenuation to

suppress effectively the beatnotes likely to be encountered under any practical operating condition. Developed in this manner the proposition is more or less self-evident, but due to the rapidity with which the audio spectrum of broadcasting apparatus is being extended, some emphasis on the matter seems desirable.

Still another factor of importance from a system standpoint is control of radio harmonics. Spurious radiation of all types is inimical to intensive development and must be avoided. The harmonic problem presents unusual difficulties since efficiency requires that the tubes in the final power-amplifier stage be used in such a manner that relatively large harmonic voltages are impressed on the output circuit, yet the harmonic power radiated must be held to an extremely small amount. A measure of the purity of wave form required may be gained from the fact that a 5-kw. transmitter operating on a good antenna is capable of establishing an electromagnetic field of approximately 0.5 v per meter at a distance of one mile. Under the circumstances, a harmonic of 0.1 per cent represents a field intensity of 500 μv per meter at the same distance. Acceptable service in many areas is being obtained with field intensities of this order of magnitude. To bring the interfering field down to the static level would probably require reduction of harmonics to 0.01 per cent or less. From an apparatus standpoint, such performance represents a very difficult problem and it is questionable if it can be justified at the present time. Practice on this point is still in a state of flux, but there is reason to believe that some intermediate value, such as 0.05 per cent, will prove to be the proper solution, and will be applied to all broadcasting stations in the near future.

One circumstance that has undoubtedly contributed to the delay in formulating definite requirements concerning the control of harmonics has been the difficulty of obtaining suitable apparatus for the evaluation of such components in quantitative terms. Field strength measuring sets have recently been made commercially available, however, which are capable of covering the necessary range in frequency and intensity. A photograph of one of these sets is shown in Fig. 3. It consists essentially of a sensitive, stable superheterodyne receiver incorporating a calibrated attenuator at the input of the intermediate-frequency amplifier and a supplementary radio-frequency oscillator from which a voltage of the frequency of the station under measurement can be introduced in the antenna circuit. The operating characteristics of such an instrument have been described by Friis and Bruce.[3] By means of a series of removable loops and coils,

[3] H. T. Friis and E. Bruce, "A Radio Field-Strength Measuring System for Frequencies up to Forty Megacycles," *Proc. I. R. E.*, **14**, 507–519; August, 1926.

the set shown is capable of measuring field strengths ranging from approximately 0.01 to 7,000 mv per meter throughout the band 250 to 6,000 kc. Apparatus of this type is now in use by the radio inspection division of the Department of Commerce.

Fig. 3—Commercial field-strength measuring set. Range: 250–6,000 kc, 0.01–7,000 mv per meter.

In the light of this discussion of present trends in transmitter development, a brief description of some recent transmitting equipments may be of interest. A particularly noteworthy example of current practice is the 50-kw. Western Electric transmitter, one of which has been placed in service within the past few months by the Crosley Radio Corporation at Mason, Ohio. Views of this equipment are shown in Figs. 4, 5, 6, 7, and 8. The transmitter proper is shown

in Fig. 4. As will be seen, it consists of seven panel units with a screen enclosure in the rear. The first unit on the left is the oscillator-modulator. This is essentially a low-power transmitter capable of an output of 50 watts and 100 per cent modulation. It is followed by three push-pull stages amplifying modulated radio-frequency power. The first power-amplifier stage, which employs two 250-watt tubes, occupies the second unit. The tubes for the second power stage, which are water cooled, and the associated tuned output circuit are contained in the third and fourth units, respectively. The final power

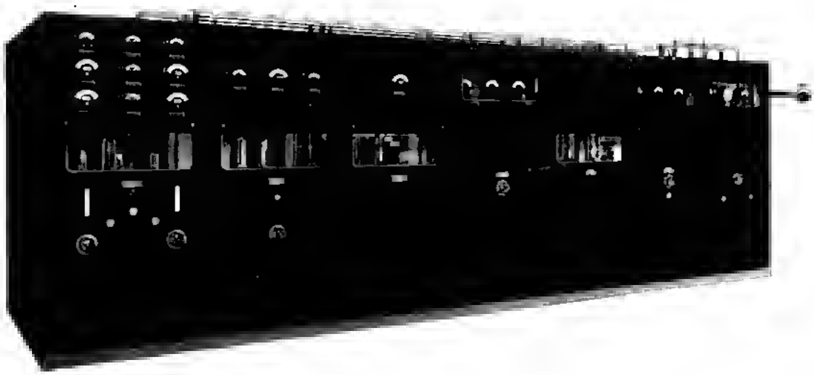

Fig. 4—Western Electric 7-A (50-kw) radio transmitter. Oscillator-amplifier assembly.

stage, incorporating six water-cooled tubes each capable of a peak output of approximately 40 kw., occupies the fifth unit. The last two panels constitute the front of an electrically screened enclosure housing the output circuits for this latter stage. All of the panels are aluminum covered with several coats of black lacquer grained by rubbing with abrasive paper. A full complement of meters is provided, the cases of which are either grounded or mounted behind glass for the protection of the operating personnel. In designing the equipment, special consideration has been given to safety. Access to the apparatus in the rear of the panels can be had only through the door on the left which is held closed by a bolt operated by the handwheel shown. The rotation of this wheel opens the transmitter control circuits putting the equipment out of operation. It then grounds the high-voltage supply busses and finally withdraws the bolt. As an additional precaution a manually operated disconnect switch for the main power supply is provided just inside the gate which can be opened on entering. Access to some of the tubes is had by opening the glass windows in the various panels, but these are

secured by electrically operated latches unless the wheel is in the grounded position. Door switches are provided in the control circuits which prevent the transmitter from being placed in operation unless all doors and windows are closed.

The power panel and rectifier assembly is shown in Fig. 5. The general arrangement corresponds to that of the transmitter proper and similar safety features are provided. In the power panel, which is on the left, are centralized the necessary power distribution and control facilities. The equipment requires a 3-phase input of approxi-

Fig. 5—Power panel and rectifier assembly for 50-kw radio transmitter.

mately 250 kw. at 440 volts. The control arrangement is such that the transmitter can be started and stopped by means of a single set of push buttons, the various circuits being energized in proper sequence by means of suitable relays and contactors. The central unit is a three-phase half-wave rectifier supplying power at 1,600 volts to the plates of the air-cooled tubes. The six-tube rectifier on the right supplies plate power at 17,000 volts for the water-cooled tubes. The filament and plate transformers and smoothing filter for the latter are located in the power room on the floor below. The filter consists of two units, one for each side of the push-pull circuit, employing a 6-μf condenser and a 12-henry inductance. Two 24-volt, 550-ampere direct generators (one a spare) supply power to the filament circuits.

These machines are slot wound and employ composition brushes, a filter consisting of a 1-mh. inductance and four 1,000-μf electrolytic condensers being used to suppress commutator and slot ripples. Grid bias voltages are obtained from a 2-kw., 300-volt unit, which is also installed in duplicate. The only other rotating apparatus is that associated with the water-cooling system. The tubes are cooled by means of distilled water which is conducted to the anodes of the amplifier tubes through insulating hose coils. The total heat trans-

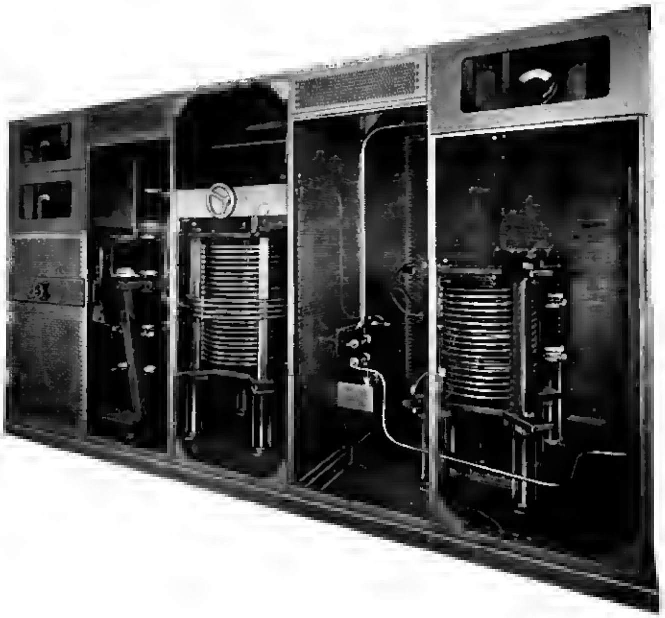

Fig. 6—Antenna coupling and tuning unit for 50-kw radio transmitter.

ferred by the cooling water is approximately 175 kw. A flow of 75 gallons per minute is maintained. Four 56-in. by 58-in. radiator units are employed, each consisting of a bank of copper tubes with spiral fins over which air is blown by a 37-in. fan. Ample radiator capacity is provided to maintain the water below 180 deg. F. under all atmospheric conditions.

To promote antenna efficiency and to reduce the intensity of the electric field in the station building, the equipment is arranged to deliver its output to the antenna through a radio-frequency transmission line approximately 500 ft. long. The line is balanced to ground and is designed for a characteristic impedance of 600 ohms. The antenna coupling and tuning unit is shown in Fig. 6. It is in-

tended for installation in a small building with a grounded copper roof located at the base of the antenna downlead. It consists of two tuned circuits, each housed in separate shielded compartments. In the photograph the doors and two of the screen panels have been removed to show the interior arrangement. The line is terminated by the parallel tuned circuit on the left which is inductively coupled to the antenna circuit to preserve an approximate balance to ground. The antenna is tuned by means of the series condenser and coil shown on the right. Accurate adjustment of the inductance of the coil is

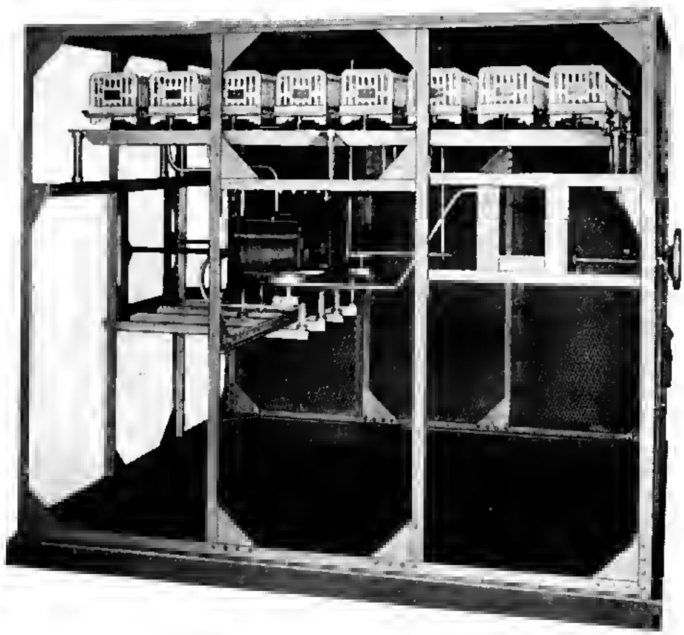

Fig. 7—Artificial antenna for 50-kw radio transmitter.

provided for by means of a short-circuited single-turn secondary which is located within the coil and arranged so that it can be rotated through approximately 90 deg. by the motor mounted on the floor beneath. The latter may be controlled from the operating room by a reversing switch placed on the right-hand panel of the transmitter assembly. A polyphase position indicator is provided to indicate the angle and movement of the secondary. The direct-current circuit of the thermal ammeter in the antenna circuit is also carried back to a bracket-mounted instrument on the end of the transmitter. These facilities permit the antenna tuning to be checked and adjustments

made to compensate for minor variations in antenna conditions without leaving the operating room.

Another feature of interest is the artificial antenna shown in Fig. 7. This unit is essentially a 600-ohm non-inductive resistance capable of dissipating approximately 75 kw. which can be connected to the output circuit of the final power amplifier stage in place of the transmission line. The heat dissipating elements consist of a series of woven wire grids mounted in the units at the top of the framework. The resistance of these grids is substantially independent of frequency, but the combination presents a slight inductive reactance which is compensated for by means of the condenser and coil combination shown. These elements are inserted into the circuit symmetrically

Fig. 8—Piezo-electric crystal mounting and temperature control apparatus.

in order to maintain an approximate balance to ground. The structure is completely shielded and is fitted with safety door and grounding switches similar to those already described.

The piezo-electric crystal mounting and temperature-control apparatus which is a part of the oscillator-modulator unit is shown in Fig. 8, dismantled to facilitate inspection. The quartz plates employed are approximately one and a quarter inches square and are cut parallel to one of the faces of the natural rock crystal. This plate is mounted between two lapped metal plates and covered with a porcelain cap carrying a terminal to which the upper electrode is connected by means of a short section of metal foil. The mounted crystal is supported by a brass block, through the center of which extends a spiral bimetallic thermostat. The top of the block is also lapped and the crystal mounting is secured to it by means of the four

springs shown. The heating element consists of a winding of resistance wire inserted in the block concentric with the thermostat. The assembly is mounted in a thermally insulated box, shown on its side in the photograph. Two of these units are provided, one located on each side of the oscillator-modulator unit directly below the window. A detachable handle for adjusting the contacts of the thermostat and a suitable thermometer extend through the box to the front of the panel. The brass mounting block is provided with a groove to receive the bulb of the thermometer. The thermostat does not operate directly in the heater circuit but controls the grid bias of a

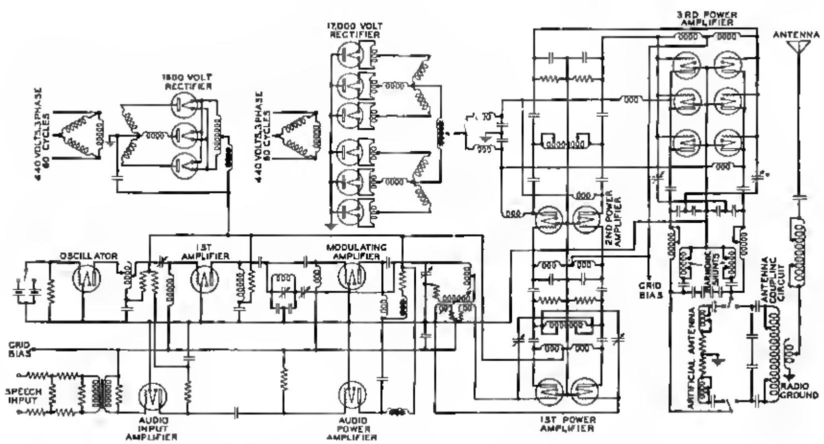

Fig. 9—Simplified circuit schematic of 7-A (50-kw.) radio transmitter.

vacuum tube in the plate circuit of which a suitable relay is placed. The quartz plates are ground to oscillate at the assigned frequency at approximately 50 deg. C, and the final adjustment is made by varying the operating temperature. The temperature coefficient of the plates varies from 30 to 100 parts in a million per deg. C. The degree of constancy attained necessarily depends on the diligence of the operating personnel. With proper maintenance the maximum deviation has been held to $\pm$ 30 cycles for long periods of time.

A simplified circuit schematic is shown in Fig. 9. Features of the electrical design are the modulation system, the push-pull amplifier stages with cross neutralization, the capacity coupling arrangement used to facilitate control of parasitic oscillations, and the provisions for the suppression of harmonics. The modulating amplifier is a 50-watt tube operating at 750 volts. The audio power stage employs a 250-watt tube at 1,500 volts. In this manner, ample audio-frequency voltage and power are provided to effect complete modulation without

distortion in the audio tube. With so powerful an equipment, the suppression of radio-frequency harmonics to a satisfactory degree becomes a difficult problem. The push-pull circuits, capacity coup-

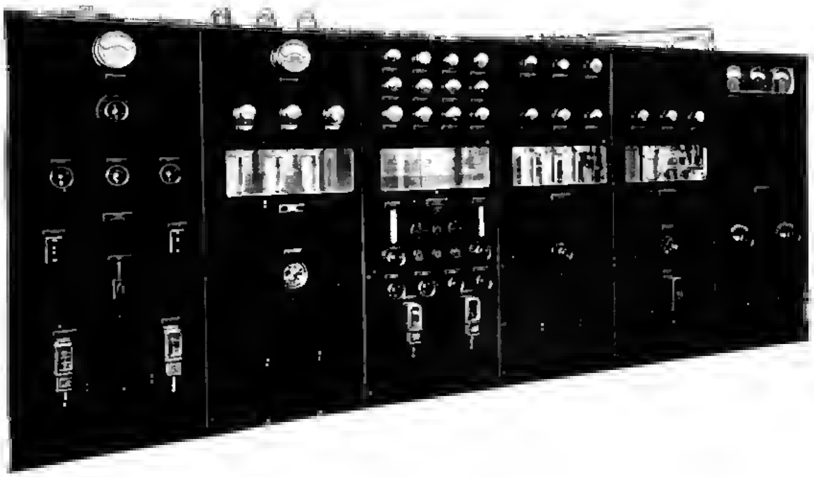

Fig. 10—Panel assembly for Western Electric 5-C (5-kw.) radio transmitter.

ling, three tuned circuits in cascade, shielding of all coils, and the two tuned shunts adjusted to the second harmonic which are connected between each side of the transmission line and ground all

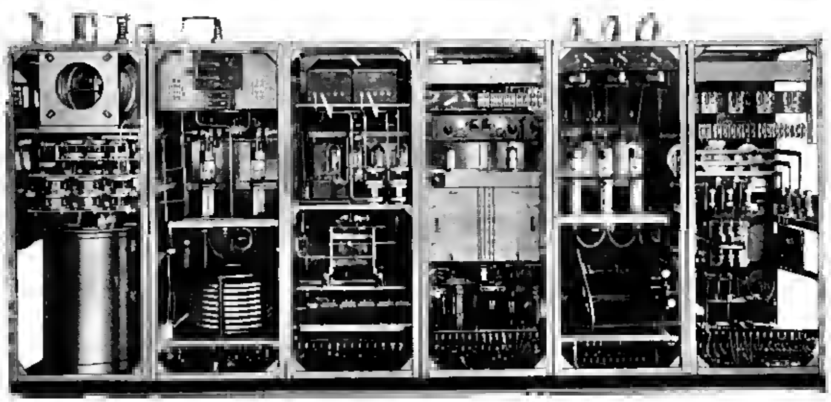

Fig. 11—Rear view of panels in 5-C radio transmitter.

contribute to superior performance in this respect. The amplitude of the harmonics radiated, as determined by field strength measurements, is less than 0.03 per cent.

A 5-kw. equipment of similar general design is shown in Figs. 10

and 11. It consists of six units: A power panel, a 10,000-volt rectifier for the water-cooled tubes, a piezo-electric oscillator unit, an intermediate amplifier unit, a power amplifier unit employing two 10-kw. tubes, and an output unit. An air-cooled transformer for the rectifier, the associated filter, and an artificial antenna are assembled in a

Fig. 12—Western Electric 6-B (1-kw.) radio transmitter.

screened enclosure in the rear of the panels. Three motor-generator sets are provided to supply filament power, grid bias, and plate power for the air-cooled tubes. A 3-phase power input of 30 kw. at 220 volts is required. The equipment is capable of fidelity in transmission comparable with that of the 50-kw. unit. The amplitude of the harmonics radiated is held to approximately 0.2 per cent.

A 1-kw. equipment of the same type is shown in Figs. 12 and 13. It involves only two panels, a piezo-electric oscillator unit and an amplifier unit. The final power stage employs a 4-kw. water-cooled tube. Two motor generators are used, one supplying 24 volts and

250 volts for filaments and grid bias, the other 2,000 volts and 4,000 volts for the plates of the air-cooled and water-cooled tubes, respectively. A power input of 10 kw. is required.

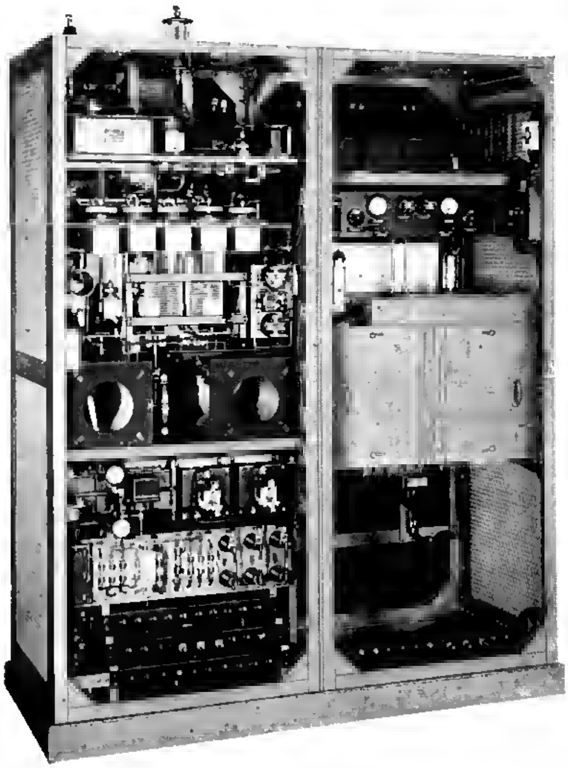

Fig. 13—Rear view of 6-B radio transmitter.

Radio Transmission Phenomena

Radio transmission phenomena in the broadcasting band have been given considerable study, and the general nature of the effects likely to be encountered are fairly well understood. Important contributions have been made by Bown and Gillett, by Bown, Martin, and Potter, by Goldsmith, and by Espenschied.[4] The second paper referred to is particularly noteworthy on account of the insight which it affords into the complexities of the process of transmission and the evidence which it presents concerning the injurious effects of frequency modulation. The latter has not yet fully received the attention which it deserves; many otherwise well designed transmitters

[4] See attached list of references.

are still in operation that are subject to frequency changes of the order of $\pm$ 1,000 cycles during modulation. This condition is not only conducive to impaired fidelity at moderately distant receiving points, but it increases interference and precludes successful common frequency operation. Fortunately, the use of automatic frequency control apparatus in its present form is effective in minimizing this effect as well as in limiting frequency variations of much longer period. It is probable, therefore, that with the more general use of automatic piezo-electric control, this matter will rapidly cease to be a problem.

As might be expected, the attention being given to intensive development has materially stimulated interest in transmission. There is a very evident need for much information of a more quantitative nature than is now available. Data concerning attenuation over city and rural areas as a function of frequency, suitable separations between stations of various powers operating on a common carrier frequency, allowable distances between transmitting stations and nearby populous communities, relative day and night ranges, relative summer and winter ranges, time of the day and season of the year at which the transition occurs, and other questions of a similar nature have become of great practical importance. The problem is rendered particularly difficult by the range in climatic, topographic, and cultural conditions which exist in the United States. Under the circumstances, there are excellent opportunities for important work in this field.

A significant tendency disclosed by recent measurement work in a number of city areas is public acceptance of and demand for field intensities which a few years ago would have been considered objectionably high. For some time it has been more or less generally agreed that a field intensity of 10 mv. per meter would afford a satisfactory high-grade broadcasting service. Recently, however, in spite of increased effectiveness due to higher degrees of modulation and in spite of continued improvement in the sensitivity of commercial receiving sets, stations establishing field strengths of 10–15 mv. per meter have been greatly handicapped in competing with others capable of producing 30–50 mv. per meter in the same areas. In several densely populated districts measurements have disclosed field intensities of 300–500 mv. per meter without any noteworthy number of complaints provided the programs were of a high character. There is little to indicate whether this tendency is the result of a decreased interest in distant stations, a desire for higher standards in reproduction involving lower noise levels, or a combination of these factors with others, but it is evidently a matter which must be given careful consideration in engineering future installations.

It is interesting to contrast this situation with that existing in some of the large rural districts as exemplified by the recent survey of conditions in the Middle West by Jansky.[5] Here over large areas acceptable service is being obtained with field strengths of 50 and 100 μv per meter. Giving due consideration to the difference in noise levels, which is undoubtedly a factor of great significance, such a discrepancy can only be reconciled on the basis of a vast difference in service standards. That such conditions will be allowed to continue for any considerable period of time is very doubtful. This is further evidence indicating that the movement toward more powerful stations is technically sound.

One phase of the transmission problem which deserves increased attention is antenna performance and design. It is an interesting circumstance that while the accurate rating of broadcasting stations is a matter of great practical concern to the industry, to date consideration has been confined to the power delivered to the antenna. Variations in the efficiency of the latter have been almost entirely neglected in spite of the fact that, due to this cause, the power actually radiated can be shown to vary through a range of four to one, or greater. There is little doubt that stations should be rated, either directly or indirectly, in terms of field intensity measurements. That such a system of rating has not already been put into effect is probably due to the lack of suitable measuring apparatus. With such equipment now available, rapid progress in this direction is expected.

An interesting feature of current American practice with respect to broadcasting antennas is a definite tendency toward the use of higher supporting structures. For the past few years, most of the towers erected have been from 150 to 225 ft. in height. Several of the more recent stations are employing 300-ft. towers, and it is not improbable that some 400-ft. structures will be put up in the near future. Since the natural frequency of grounded steel towers of these dimensions falls in the broadcasting band and may approximate the assigned operating frequency, low-capacity porcelain insulators are inserted at the base. The latter effect a considerable increase in the natural frequency of the towers and preclude serious distortion in the field intensity pattern due to heavy induced currents in the steel. The antennas themselves are of such dimensions that the current antinode is positioned well up on the vertical section. The effect is to concentrate the radiated power along the ground plane and to increase materially the field intensity in the local service area. Such antenna systems promise a better economic balance between the in-

[5] See attached list of references.

vestment for generating modulated radio-frequency power and that for radiating it.

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